Stability Enhancement of DFIG Fed Wind Energy Conversion System Using Crowbar Protection Scheme

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Abstract - *Wind energy is one of the fastest growing non conventional energy sources. Doubly Fed Induction Generator is often ally used nowadays in wind turbine. It is very sensitive to the grid disturbances, faults, and can harm the power electronic devices due to over voltages and over currents. Therefore, protection elements like Crowbar, SDBR, DC Chopper are used to disconnect the machine during unhealthy conditions. In this paper the crowbar protection method is used to ride through these disturbances. The behavior of these machines during grid failure or collapse is an important issue for us. DFIG consists of a wound rotor induction generator with slip ring and a partial scale power electronic converter. Vector control technique is applied to rotor side converter for active power control and the voltage regulation of wind turbine. All electrical components are simulated in MATLAB/ SIMULINK 2016 software. Simulation results show the performance of DFIG control schemes with or without crowbar scheme.*

***Key-words*: DFIG, Wind energy conversion system, Wind turbine, Crowbar, Control technique for generator, DC link, RSC, GSC.**

I. INTRODUCTION

For better growth, it's very necessary for energy need; utilization of nonconventional sources like wind, geothermal, hydro, biomass, solar, etc should be used broadly. In the sustainable energy system, conservation of energy and the use of renewable source are the key paradigm. The need is to integrate the renewable energy like wind energy into the power system is to make it possible to reduce the environmental impact on conventional plants. One of the most important features of DFIG is its capability of handling 20-30% of total power which leads to reduce the losses in the power electronic equipments used in the network. Moreover, because of DFIG's capability in decoupling the control of power (both P and Q), another thing these types of generators show good behavior in system stability during unhealthy or short circuit or in faulty condition as compared to other generators. There has been an extensive growth and quick development in the field of wind energy in recent years.

The power rating in variable frequency ac/dc/ac converter (VFC) is only 25%-30% of the induction generator power rating, over current can lead to the destruction of the converter so we are using crowbar protection scheme so that our system can withstand during abnormal condition. Doubly Fed Induction Generator (DFIG) is connected to the grid through Rotor Side Converter (RSC) has stated that the sensitivity of DFIGs to change in their terminal voltage is the main drawback of this equipment. This weakness leads to the destruction of the RSC, especially when an external fault occurs. Typical solution for industrial application is using crowbar protection. The disadvantage of using this topology is that RSC has to be disabled and consequently, the generator consumes reactive power leading to deteriorate the grid voltage.

II. DOUBLY FED INDUCTION GENERATOR

Variable speed turbines are more popular than fixed wind speed turbine, due to its ability to capture more energy from wind, improved power quality and reduced mechanical stress on the wind turbine. One of the most frequently used generators with variable speed wind turbines is the DFIG which is an interesting alternative with a growing market. It can run at variable speed but produce a voltage at the frequency of the grid. In contrast to a conventional simple induction generator the electrical power generated by a DFIG is independent of the speed. Therefore it is possible to realize a variable speed operation which requires adjusting the mechanical speed of the rotor to the wind speed so that the wind turbine operates at the aerodynamically optimal point over a certain wind speed range. DFIG has various advantages like its low converter rating (The converter rating of the DFIG is 25-30% from the machine rating) consequently its relatively high efficiency, lighter in weight, its low cost and its capability of decoupling the control of both active and reactive power. Therefore, the DFIG has its distinguished place among many variable speed wind turbine generators.

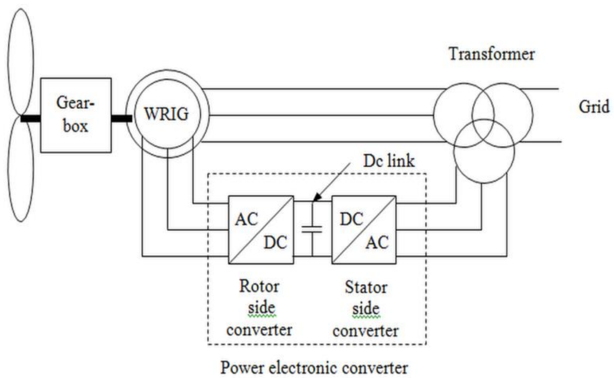

Fig -1: DFIG Scheme

DFIG Modes of operation-

The DFIG system can inject power into the grid through both the stator and rotor, while the rotor will absorb power. This depends upon the generator rotational speed or in other words, its mode of operation. If generator operates in super-synchronous mode, power will be delivered from rotor through the converters to the network, but if the generator operates in sub-synchronous mode then the rotor will absorb power from network with the help of converters. These two modes of operation are illustrated in fig. 3.2 where ω_s is the synchronous speed and ω_r is the rotor speed.

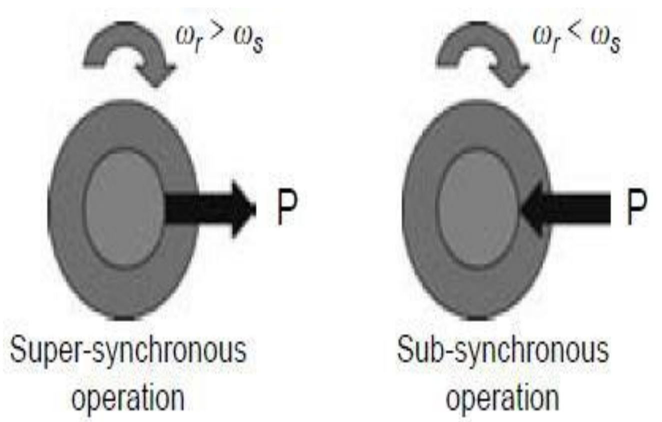

Fig-2: DFIG Modes of operation

Therefore, depending on the sign of the slip, it is possible to distinguish two different operating modes for the machine:
($\omega_r > \omega_s$) $\Rightarrow$(s < 0) Super-synchronous operation ($\omega_r < \omega_s$) $\Rightarrow$(s > 0) Sub-synchronous operation Assuming, P_m is the mechanical power delivered to the generator, P_{ag} is the power at the generator air gap, P_r is the power delivered by the rotor and P_s is the power delivered by the stator. P_g is the total generated power and delivered to the grid side.

(a) Super-Synchronous Mode-

In this mode of operation, the slip, the air gap power, and the mechanical power are negative. In addition, as can be deduced from figure 3(a), the magnitude of the air gap power $|P_{ag}|$ is less than the magnitude of the mechanical power $|P_m|$. Consequently the rotor power has to be positive. Therefore, the remaining surpluses power sP_{ag} is absorbed by the grid after providing for the rotor cupper losses P_{rcl}. As seen in fig. 3.3 which represents the power flow diagram for this mode of operation, the total generated power in this situation is equal to ($P_s + P_r$).

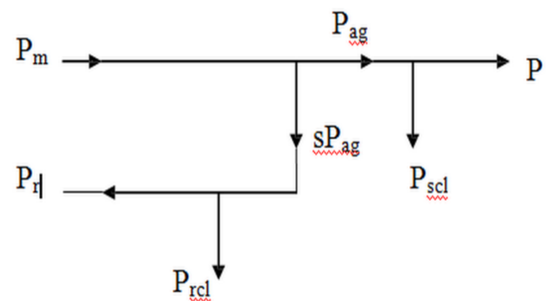

Fig-3(a): The power flow diagram of the DFIM in super-synchronous mode

(b) Sub-Synchronous Mode-

In this mode of operation, the air gap power, and the mechanical power are negative and because the rotor speed is less than the synchronous speed the slip will be (0<s<1). From it can be concluded that $|P_{ag}| > |P_m|$. Consequently the rotor electrical power sP_{ag} should be negative. As seen in fig. 3.4 which represents the power flow diagram for this mode of operation, the resultant generated power is equal to ($P_s - P_r$).

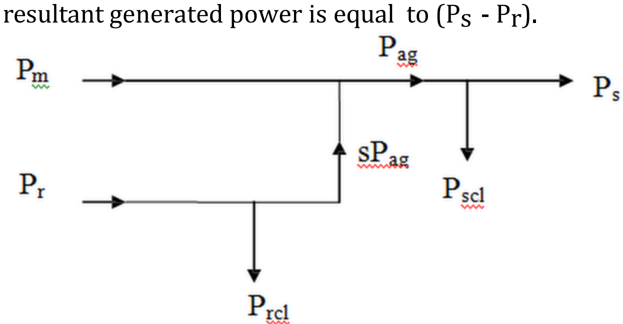

Fig-3(b): The power flow diagram of the DFIM in sub-synchronous mode

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III. DFIG PROTECTION TECHNIQUES

There are so many protection techniques like DC Chopper, Dynamic braking register, crowbar for DFIG but we are focused on Crowbar Protection technique which is explained in the detailed.

Crowbar Technique-

Crowbar is actually of 2 types, used in two ways one in Active other is Passive way. We are using active crowbar to protect the Rotor Side Converter (RSC) from tripping because of over currents . The crowbar limits the currents and provides a safe path for faulty currents by short circuiting the rotor with some combinations of resistors. When the crowbar is in ON condition the RSC pulses are totally disabled and our machine will behave like a (SCIM) squirrel cage induction machine directly coupled to the grid side.

The magnetization of the machine which was provided by the Rotor Side Converter during the normal operation is lost and the machine will draw large amount of reactive power from grid, which is called grid codes. Though, triggering of crowbar circuit produces high stress to the mechanical component of the system. This scheme (crowbar protection) is reliable just because of its low cost and simple construction. Schematic diagram of DFIG with crowbar protection is drawn below.

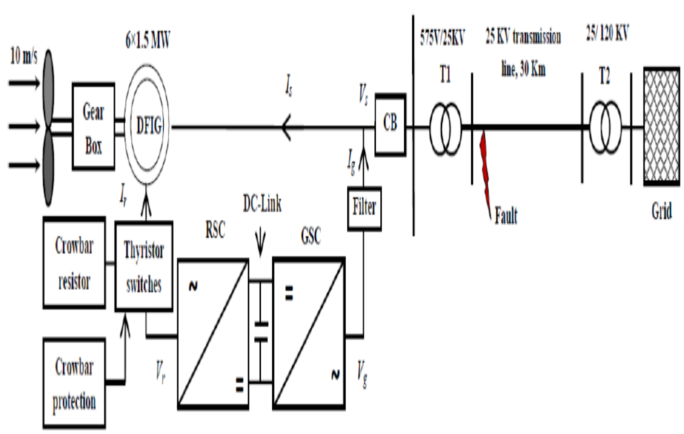

Fig -4: DFIG with Crowbar protection scheme

Crowbar protection can be designed by connecting 3 phase resistance. It is connected on the rotor with the help of a controllable breaker. since, it is not the real case i.e.(in reality, the crowbar may be made up of the combination of one or many resistances fed through a switched rectifier bridge), but it may be quite sufficient to assess the overall impact of crowbar protection on LVRT.

The breaker is normally kept open, but it is closed during short-circuiting the rotor through the resistance, if any one of them either the rotor current or the DC-link capacitor voltage goes too high. At the same time the switching of RSC is stopped. The value of crowbar resistance is selected as 20 times high the rotor resistance. The choice of crowbar resistance is an important thing because; as it determines how much power i.e. reactive power the DFIG will draw while the crowbar is inserted to the circuit. When the crowbar is disconnected from the system the rotor current and the DC- link voltage will return to their normal operating range and RSC is reinserted.

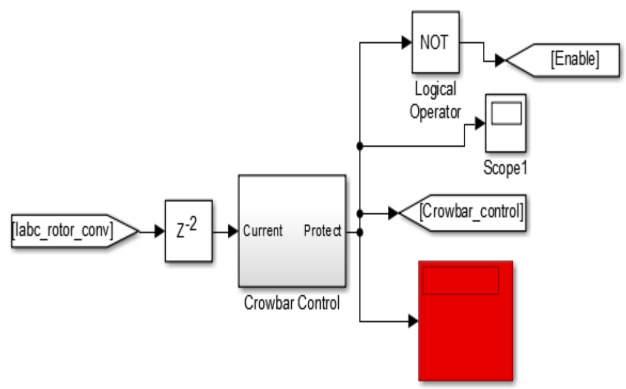

Fig -5: Simulink diagram of Crowbar

Table -1: Parameters for 1.5 MW DFIG

Rating	1.5 Mw
Stator voltage (L-L. RMS)	575 V
Number of pair pole	3
Stator resistance	0.00706 pu
Stator inductance	0.171 pu
Mutual inductance	2.9 pu
Rotor resistance	0.005 pu
Rotor inductance	0.156 pu
Combined inertia constant of the generator and the turbine	5.04 s

Table for 1.5 MW DFIG is drawn above. We have taken 4 units of them i.e. total of 9 MW wind farm. Crowbar is effective for low scale wind farm.

IV. SIMULINK MODEL-

This is the basic model of 9MW wind farm drawn. The parameters which are taken to further calculations are mentioned in the table. Control circuitry of Wound rotor, RSC, GSC, wind turbine and crowbar circuit are put inside the subsystem of DFIG wind turbine. Subsystem of wind turbine is drawn below after that the inner control circuit of crowbar is drawn below.

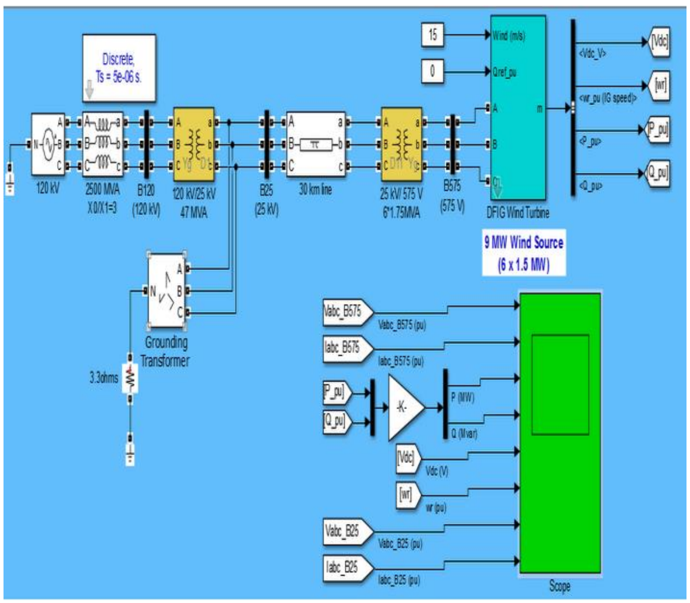

Fig-6: DFIG connected with Convectional protection (Crowbar) system

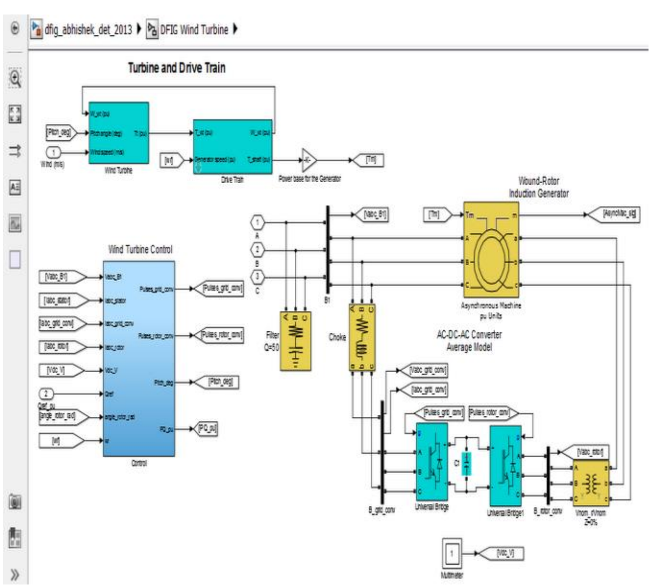

Fig-7: Simulink diagram of DFIG fed Wind energy subsystem

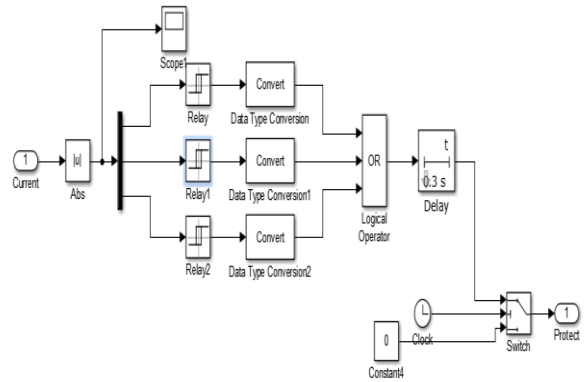

Fig -8: Inner control circuit of Crowbar

V. SIMULINK RESULTS

There are different output parameters like phase voltages, line currents, reactive power, active power, temp., and rotor speed etc. for wind power system shown below by using crowbar system.

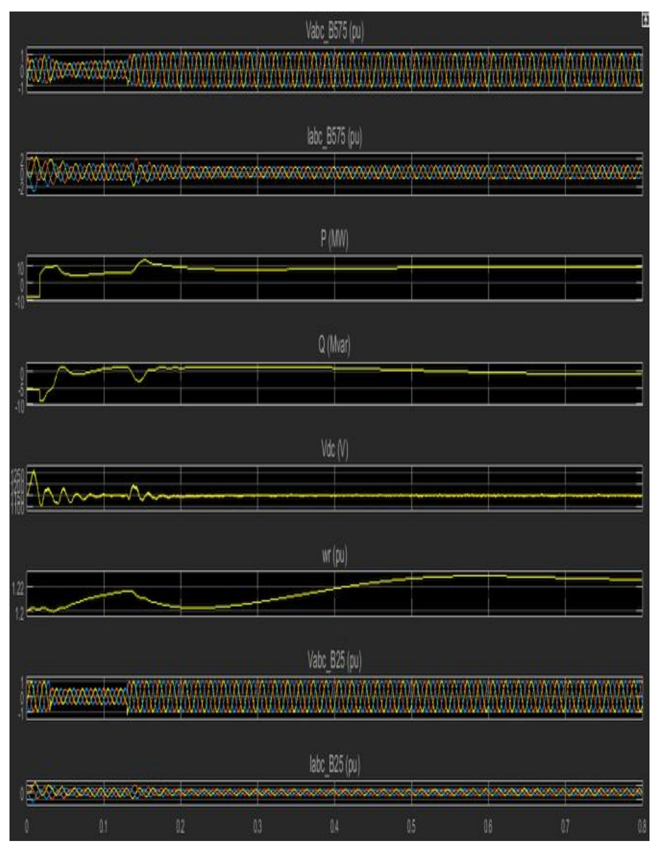

Fig -9: output waveforms of different parameters

VI. CONCLUSION

In this paper, Simulation of wind energy conversion system which is connected with the grid is done with the help of MATLAB/Simulink. Low Voltage Ride Through is one of important feature for wind turbine system. Crowbar is the conventional method with less cost but draws more reactive power Waveforms for different parameters like rotor speed, wind speed, temp., pitch angle and the torque being control to provide the active and reactive power supply drawn above. The output of this model gives us when there is any types of disturbances, fault, transients come into the system crowbar will protect the generator for that period of time by disconnecting them for the main circuit. Further research should be focused on control strategy of LVRT with the less complexity, cost also with support the reactive power during faults.

VII. REFERENCES

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BIOGRAPHIES

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